EVALUATION MODELS FOR CONTAMINATED SITES – BIOLOGICAL SISTEM AT RISK

M. Golomeova, B. Krstev, B. Golomeov and A. Zendelska
University "Goce Delcev" Stip, Faculty of Natural & Technical Sciences - Stip, Macedonia

A. Krstev
University "Goce Delcev" Stip, Faculty of Computer Science, Stip, Macedonia

ABSTRACT
The paper presents the different methods that can be used correspond to three types of approaches, testing, monitoring, and modeling: experimental models, in situ indicators and mathematical models, and choice of model for contaminated sites – biological system at risk.

АБСТРАКТ
Во трудот се прикажани три различни методи кои може да се искористат подеднакво за пристапување, тестирање, мониторинг и моделирање: експериментален модел, in situ показател и математички модел. Во трудот е прикажан и избор на модел за контаминирани предели.

1. INTRODUCTION

The different methods that can be used correspond to three types of approaches, testing, monitoring, and modeling (Chapman, 1989, 1991).

- *Experimental models:* these are the *conventional assays* of the occurrence, behaviour, and effects of pollutants (1) at different levels of organization, that is, laboratory assays *(monospecific tests)* and different integrated assays (from multispecific assays up to mesocosms) and (2) for different types of pollutants, from the pure substance to the polluted medium *(bioassays).*
- *In situ indicators,* relative to the environment and to the living elements that populate it or living elements introduced on the site (measurement of pollutants and eco-epidemiological data).
- *Mathematical models.*

2. DEFINITIONS

For Covello and Merkhofer (1993), this categorization is not absolutely rigid; for example, some mathematical models may be used to express results of conventional assays. Moreover, the distinction between a laboratory assay and an *in situ* indicator is fundamentally arbitrary. An ecotoxicity assay is a microcosm, in the first sense of the term, that is, a 'world in miniature' that attempts as far as possible to represent the complexity of nature, while the data collected on the site can be considered the result of a single experiment on a grand scale. The bioassays have been linked to ecotoxicity assays, because they have been conducted according to the same standard protocols, but they can be considered a particular form of *in*

situ indicators, since they use a polluted medium rather than a pure substance.

1. Experimental Models

Experimental models correspond to the 'physical models' of Suter (1993a). They are physical or biological systems simulating under controlled and simplified conditions the progress of the whole or part of an ecotoxic process. In another example, in order to determine the acute toxicity of a pesticide on trout, an ecotoxicity assay is done: a fixed number of fish are introduced in a limited environment and some milligrams of pesticide are added. After 24 or 48 hours, the dead fish are counted.. Ecotoxicity assays are thus sufficiently good physical models, but they must be augmented by other elements that enable us to evaluate more precisely what happens in nature interspecific extrapolation models. The final expression of an ecotoxicity assay can take di ferent forms: direct expression of the desired result {mortality of a certain number of fish at each concentration tested) or a mathematical model linking the numeric variables.

Monospecific laboratory assays with pure products administered to some laboratory species are the most widespread form of experimental assays, but it is possible to create larger and more complex models, ranging from multispecific assays to mesocosms (integrated assays). The results obtained with these models are more difficult to use for the evaluation of ecological risk.

The authors of I2C2 (1994), with good reason, distinguish two categories of tests: *conventional tests,* standard or not (routine assays), and *parametric tests.* Conventional tests serve as the basis for risk evaluation, while parametric tests serve to extrapolate the values of standard tests to other situations, for example, to adjust the results of a conventional test, conducted under a determined temperature, to the range of temperatures found in natural conditions.The advantages and disadvantages of conventional laboratory tests are well known; their chief advantage is that they are reproducible. They are generally cheaper and quick, but they have little 'ecological realism'. Besides, they are not indispensable, as they contain much that is only a model of the elements that constitute the scenario. Bioassays are experimental devices designed to measure the effects of the mediums from a site under laboratory conditions. Most bioassays are done in conditions identical to those of conventional ecotoxicity assays.

2. *In Situ Indicators*

In situ indicators are: The measurements taken on the site to determine the concentration of pollutants, Eco-epidemiological observations designed to bring toxic effects to light. These two types of indicators are to be found in natural ecosystems or in manipulated ecosystems. The nature, advantages, and disadvantages of the different indicators and their use in risk evaluation protocols will be discussed later.

3. *Mathematical Models*

Mathematical models are divided into two main categories: statistical models; mechanistic models (deterministic or stochastic)

The statistical models have three principal applications in risk evaluation: to test hypotheses; to describe events and phenomena; e, in the evaluation of contaminated sites, to compare polluted sites to reference site, to extrapolate. Tests of hypotheses have been used, for exampl s. The null hypothesis signifies that there is no significant difference between the two situations and to reject this hypothesis is to say that there is a difference. Two types of errors are conventionally associated with these tests. The first type of error is the rejection of the null hypothesis even when it is true (we see a difference even when there is none) and the second type of error is the acceptance of the null hypothesis even when it is false (we do not see a difference even when there is one); a is the probability of making an error of the first type and (3 is the probability of making an error of the second type. The validity of the test is defined as (1 - f5). It is a prudent approach when we don't want to conclude too quickly (and erroneously) about the efficacy of an amendment, but in the case of a toxin, we risk concluding (wrongly) that there is no effect. In the case of comparison of two polluted sites, it is better to be mistaken in concluding a

difference, that is, that a site is polluted even when it is not, than in concluding that it is not polluted even when it is.

Statistical models also contribute to the description and interpretation of test results, for example, the classic log(dose)-integer that links the concentration of the toxin to mortality. A more detailed presentation of various statistical models can be found in Covello and Merkhofer (1993).

Finally, *statistical models* (regression models) are the source of algorithms that serve to extrapolate, for example, from the tested species to the species present in the natural environment, or to doses that are outside the range tested, or even to different products.

Stochastic models are based on the uncertain character of events. These models, based on years of regular measurements, are well adapted to meteorological predictions, for example, or predictions of automobile accidents, but they necessitate a very large quantity of data in order to be useful.

Deterministic models correspond to those generally spoken of as models, that is, a mathematical formalization of relations between the different elements of the system, based on the description of physical, chemical, and biological phenomena. The two general types of models are models of *occurrence* and of *behaviour,* which simulate the occurrence and transfer of products in the environment and the models of effects at different levels, at the organism level (toxicodynamic models, for example) or at the population level.

The *validity* of models developed for the evaluation of ecological risk is very often disputed. As Suter (1993a) has shown, part of the difficulty arises from an insufficiently precise definition of what is understood by validation, which can be stated as follows: the model corresponds exactly to reality; the model has made satisfactory predictions.

The first is much too absolute. A model must have been verified in some specific cases, but by definition, it is designed to evaluate a situation that has no precedent. According to Covello and Merkhofer (1993), a model must always be 'false' This is possible for the modelling of small, relatively simple systems corresponding to a situation of small amplitude (for example, the transfer of herbicides of the same chemical family in corn leaves), but not feasible when the models increase in size and complexity because of the time and space that would be required. Consideration in regulatory norms is often cited as a proof of validity of models. In fact, it means simply that the models are the object of a general consensus (or have been imposed), but that does not mean that they are the best adapted to the situation, or the most scientifically founded. Theoretical models have been proposed to guide the selection of models, but they are not often used (Suter, 1993a; Covello and Merkhofer, 1993).

2.1. Choice of Model

The choice of model obviously depends on the chosen scenario, but in fact, the possibility of realization of a scenario is very dependent on the available models. The model is generally constructed from existing submodels or those generated during the course of evaluation, constituting the different links in the causal chain. This construction of the model from very disparate elements is characteristic of risk evaluation; the model is a composite, according to the definition of Covello and Merkhofer (1993). The scenarios, like the corresponding models, are simple or complex, partial or total. Many models are only *partial,* representing only the exposure phase or one part of it. For example, there are models that describe only the occurrence of a product or its biotransformation in an environment; others characterize only the means of exposure. Models gain *overall* in considering more various situations, for example, in incorporating a larger number of stages. A model linking the environmental concentration to the *internal dose* will be more total than a model linking the environmental concentration to the external dose. In order to construct the definitive model, it is customary to combine several partial models, for example, a partial model describing the occurrence of a product will be associated with a model describing the movements of populations at risk.

The *complexity* increases if the content of the different steps is more detailed. The choice between a simple and complex model, and between a total and a partial one, depends on the objects of the study indicated in the scenario and the significance of the necessary data; simple and total models will suffice for a rapid evaluation of risk related to a chemical product. The detailed scenarios necessitate elaborate, complex models and a considerable number of data that it is not always possible to obtain, which can lead to several decisions: generate the models and missing data by specific experimentation or by extrapolations.

The term *global* would be preferable, but it is already used to designate scenarios of continental or global geographic scale, we use the general terms *external dose* and *internal dose* to designate, respectively, the quantities or concentrations present in the environment (in contact with the organism) and present in the organism, define a more simple scenario, possibly by redefining *(he final points*, and construct a model less demanding in terms of data or making better use of the available data.

A complex model is not always indispensable. The essential problem is not to study the entire ecotoxic process to its smallest detail. The integral understanding of the molecular mechanisms is not indispensable to linking the doses and the toxic effects. Bioassay results and the existence of eco-epidemiological data also ensure a direct link between the environmental concentrations— more rarely the internal doses—and toxic effects.

The scenarios are simplified representations and compromises, which is why there are several possible scenarios that attempt to describe the same situation, and, as a corollary, *different results,* independent of the uncertainty associated with the parameters of the model (Dobsoi\, 1993; Nillson et al., 1993). Suter compares risk evaluation to what happens in a court: there is a presumed culprit, the pollutant, and a presumed victim, the polluted. The court (risk evaluator) will use all possible means to attempt to reconstruct the sequence of events (the scenario) as exactly as possible by the presentation of material proofs, such as confessions, expert techniques, etc. (the different approaches and methods of risk evaluation). The differences can be very large, whence the acknowledged necessity of a large professional experience and a significant weight to human judgement. But contrary to a process in which there are no absolute proofs of the variability of the verdict (one cannot commit the same crime twice), it is possible (at least theoretically) to develop various scenarios and verify the one best adapted to the actual development of the situation.

Iriis example shows also the significance of *expert judgement,* representing the state of the evaluator's understanding. Suter (1993a) remarks that the results obtained by the judgement of experts are not necessarily worse than those from a model based on more scientific data (a mathematical model, for example), but there are two disadvantages:

- the procedure is less transparent to others;
- experts have the tendency to have an exaggerated confidence in the value of their evaluations, which biases the final result.

The credibility of a 'scientifically based' model could be better, but that supposes: the belief in a certain truth to science; that the model rests on true and verifiable scientific bases (in the sense of Forbes and Forbes, 1994).

Differing results are obtained depending on the type of model chosen, but also depending on the scenario envisioned. This average approach is not suitable to all cases, particularly when it is necessary to evaluate the risk to sensitive groups, for example, sub-populations that, for various reasons, consume much larger quantities of fish. This problem is resolved by explicitly incorporating sensitive groups in the exposure scenario or by defining the maximal rather than average values, in estimating the consumption of fish by the population. This strategy, called 'worst case', or even 'extreme case', is systematically used, but one must not forget that the risk evaluation must remain *reasonable.*

3. RESULTS

Table 1. Results from investigations

POSITION	PRODUCT	Average values (µg/kg)				
		Fe	Mn	Pb	Zn	Cd
Jagodina district 1,5 km from tailing dam	GOAT MILK	1,20	0,10	0,024	3,80	0,005
	COW MILK	1,05	0,10	0,042	1,20	0,002
	PEARS	2,95	0,55	0,141	2,10	0,022
	PLUMS	1,70	0,45	0,079	0,40	0,006
	PAPRIKAS	6,35	0,80	0,178	1,40	0,023
	TOMATO	3,45	0,70	0,127	1,50	0,023
	PATATO	4,95	1,35	0,165	7,00	0,050
Palin Valey	CROPS	4,10	1,50	0,040	5,00	0,030
Sasa School 4 km from tailing dam	APPLE	3,10	0,40	0,160	0,50	0,008
	BEANS	25,65	3,80	0,040	16,60	0,030
	PATATO	2,75	1,20	0,060	3,20	0,020
	CROPS	5,20	0,70	0,090	5,15	0,020
	TOMATO	4,25	1,90	0,055	2,45	0,060
	APPLE	2,45	0,85	0,210	1,50	0,015
RAZDOL 6 km from Tailing dam	TOMATO	3,35	0,65	0,070	1,05	0,020
	PLUMS	3,50	1,10	0,080	0,85	0,003
	APPLE	2,30	0,45	0,090	0,10	0,001
	BEAN-PODS	3,75	1,65	0,150	1,80	0,005
Kalimanci Village 19 km from Tailing dam	TOMATO	4,40	0,95	0,065	1,70	0,020
	CROPS	4,15	1,80	0,070	4,25	0,010
	ONION	4,95	1,15	0,140	3,75	0,020
	PAPRIKAS	4,35	0,90	0,100	2,45	0,040
Istibanja 32 km from Tailing dam	TOMATO	7,55	2,15	0,090	2,60	0,020
	PATATO	2,45	1,80	0,080	1,50	0,000
	ONION	4,90	3,85	0,125	4,30	0,045
D.Balvan 62 km from Tailing dam	APPLE	1,30	0,35	0,070	0,00	0,002
	GRAPES	2,00	0,45	0,045	0,25	0,004
	PEARS	2,40	0,00	0,060	0,75	0,002
	PLUMS	1,35	0,700	0,050	0,15	0,001
	TOMATO	6,15	1,75	0,095	2,20	0,030
	EGG- PLANT	2,75	0,80	0,090	1,70	0,025

Table 2. Results from investigations

POSITION	PRODUCT	Average values (µg/kg)				
		Fe	Mn	Pb	Zn	Cd
Jagodina district 1,5 km from Tailing Dam	CROPS	65,10	4,00	0,000	13,20	0,000
	CABBAGE	7,05	0,95	0,035	3,80	0,001
	PATATO	11,60	1,05	0,500	5,10	0,003
Palin Valey	CROPS	32,10	3,85	0,050	20,80	0,040
Sasa School 4 km from tailing dam	BEANS	70,55	12,45	0,040	49,80	0,065
	TOMATO	4,45	0,90	0,710	2,50	0,010
	PATATO	17,80	18,50	0,150	5,75	0,010
	APPLE	9,50	0,60	0,035	3,60	0,001
Samardjiski district 5 km from	PATATO	60,15	12,90	0,000	29,60	0,000
	BEANS	60,15	12,50	0,000	29,00	0,000
	CHESTNUT	7,60	4,70	0,005	5,25	0,010

Tailing Dam	PATATO	20,70	1,35	0,165	6,45	0,020
	APPLE	7,15	0,25	0,110	7,15	0,001
RAZDOL 6 km from Tailing dam	CROPS	65,90	2,20	0,000	20,50	0,000
	PUMKIN	6,70	0,30	0,080	3,85	0,001
	PATATO	19,45	1,20	0,120	5,85	0,004
	TOMATO	5,15	0,55	0,110	2,10	0,002
	PAPRIKAS	3,90	1,10	0,105	7,15	0,001
	LEEKS	4,00	0,75	0,130	5,40	0,020
Kalimanci Village 19 km from Tailing dam	CROPS	24,85	17,90	0,000	4,00	0,000
	PUMKIN	4,35	0,20	0,110	0,75	0,015
	LEEKS	9,50	0,60	0,110	3,00	0,002
	PAPRIKAS	5,95	1,30	0,100	2,25	0,001
	PATATO	5,05	0,75	0,090	0,35	0,001
Istibanja 32 km from Tailing dam	ONION	5,45	1,50	0,130	4,85	0,003
	BEANS	64,40	17,90	0,005	36,60	0,000
	PAPRIKAS	3,90	0,40	0,040	2,25	0,005
	RICE	5,60	50,75	0,180	2,15	0,020
	CARROT	30,00	1,00	0,055	2,15	0,080
D.Balvan 62 km from Tailing dam	LEEKS	5,60	1,45	0,130	1,95	0,004
	CABBAGE	5,35	11,25	0,165	5,35	0,004
BOZANICA	GOAT MILK	0,50	0,00	0,008	4,75	0,000
	COW MILK	0,00	0,05	0,030	0,00	0,004
Samardjiski district 5 km from Tailing Dam	GOAT MILK	1,40	0,00	0,000	4,50	0,000
	COW MILK	0,00	0,05	0,030	6,90	0,004
Samardjiski district 5 km from Tailing Dam	GOAT MILK	3,90	0,00	0,006	5,00	0,000
	COW MILK	0,00	0,04	0,090	3,10	0,000

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